A STUDY OF ACOUSTIC FLUCTUATIONS FROM BASIN-SCALE PULSE TRANSMISSIONS

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LONG-TERM GOAL

The long-term goal of this research is to develop our understanding of long-range oceanic pulse propagation through random sound speed fields, like those caused by internal waves, so that we can use acoustic fluctuations like temporal, vertical, and horizontal coherence to infer average internal-wave spectral parameters.

SCIENTIFIC OBJECTIVES

The scientific objective of this work is to develop analytical expressions for temporal, vertical, and horizontal coherence of the acoustic field as a function of internal-wave model parameters and compare these analytic model predictions to data and numerical models. Analytical results for these second moments are important because they eliminate the need for time-consuming Monte-Carlo runs and they allow an efficient treatment of the inverse problem[1]. A key element of this work is to understand the limits of geometrical optics (GO) at frequencies of order 75-Hz, and to evaluate the relative contributions of medium decoherence and intermittent structure[2] on the acoustic coherence functions.

It has been shown that acoustic fluctuations from energy which has ensonified the upper few hundred meters of the ocean cannot be explained using the Garrett-Munk (GM) internal wave model[1], so a secondary, oceanographic objective of this work is to explore upper ocean internal-wave models.

APPROACH

We are analyzing data from the Acoustic Thermometry of Ocean Climate (ATOC) North Pacific network, and the North Pacific Acoustic Laboratory (NPAL). The ATOC data consists of 8 months of 75-Hz pulse transmissions from a bottom mounted source on Pioneer seamount (off San Francisco), which were received on two, 40 element moored vertical line arrays (VLAs) one located off the island of Hawaii and one located near Kiritimati. For NPAL we are analyzing a year long sequence of transmissions from an ATOC source deployed off Kauai which were received on five VLAs (one 40 element and four 20 element

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VLAs) arranged in a billboard configuration located on Sur Ridge off Monterey California. The NPAL billboard array obtained data from June 1998 to August 1999. For the NPAL and ATOC data we are analyzing the acoustic fluctuations of the early ray-like arrival pattern and we are quantifying travel time variance, temporal, vertical, and horizontal coherence as a functions of Julian day.

In parallel we are developing computer codes to evaluate acoustic coherence functions utilizing assorted internal-wave models. If it is assumed that medium decoherence dominates over intermittent structure then the coherence calculation involves evaluating the phase structure function D between two points (1) and (2) which may be separated temporally, vertically, or horizontally; that is

$$D(1,2) = < (\delta\phi(1) - \delta\phi(2))^2 > \tag{0.1}$$

where $\delta\phi$ is the phase fluctuation computed using GO[3]. The coherence function is expressed in terms of D by

$$< \psi(1)\psi^*(2) > = \exp\left(-D(1,2)/2\right). \tag{0.2}$$

In general the calculation of D is a large undertaking involving double integrals over the internal wave covariance function, therefore we are assembling a cluster of Pentium PCs to handle this task. We are also doing parabolic equation and GO modeling of sound propagation through internal waves to evaluate the relative contributions of medium decoherence and intermittent structure on the acoustic coherence functions.

During the NPAL transmissions we collected in-situ observations of internal waves and mesoscale eddies in the upper 800m of the ocean. These observation were made to address the issue of the non-GM quality of the internal wave spectrum in the upper ocean. In August of 1998 we made a hydrographic transect along the transmission path and deployed 2 internal wave monitoring moorings equally spaced between Kauai and Sur ridge. The mooring were equipped with temperature, conductivity and pressure sensors, temperature only sensors and ADCP and these moorings recorded data for 1 year at sample periods between 20 minutes and 200 sec.

WORK COMPLETED AND RESULTS

This year we have analyzed the temporal and depth coherence of data from the ATOC Acoustic Engineering Test (AET) [4-5], and compared these observations to predictions based on the GM internal wave model and Eq. 2[1]. We computed observed vertical coherence lengths of 300m and coherence times of 12 minutes both of which were almost independent of wavefront ID. Predictions of depth and temporal coherence, after fitting the travel time variance with a GM energy value of roughly 0.5 the reference, were 200m and 9 minutes. We also computed expected horizontal coherences for the AET environment using both GM internal waves and a mesoscale model based on 3 years of TOPEX/POSEIDON sea

surface observations. Surprisingly the mesoscale contribution to the horizontal coherence is substantial and this will be an issue for the NPAL data analysis[3].

For the ATOC data analysis at the Hawaii VLA we have computed the combined time/depth coherence along a wavefront and we find higher coherence levels than for the AET even though the ranges are comparable. This effect may be due to the removal of source motion; AET had a source suspended from R/P FLIP while the ATOC data had a bottom mounted source. We have also computed the 2-d phase and log-amplitude covariances to test the applicability of Eq. 2. In general, computation of the 2-d phase structure function from the data is problematical because of fade-outs.

Finally we have collected and are processing the large volume of oceanographic observations of internal waves and mesoscale eddys from the NPAL moorings and cruises. Preliminarily we see large differences between our upper ocean internal wave observations and the GM model particularly at low frequencies and at the very highest frequencies. This data will be important in the interpretation of the NPAL acoustic transmission data.

IMPACT/APPLICATION

These observations and modeling of acoustic coherence have clear Navy signal processing implications; i.e. matchfield processing, array performance.

TRANSITIONS

None at this time.

RELATED PROJECTS

1. Effects of small-scale ocean fluctuations on ocean-acoustic transmission, S. M. Flatté.
2. North Pacific Acoustic Laboratory; P. F. Worcester and R. C. Spindel
3. Ocean acoustic observatories: Data analysis and interpretation; P. F. Worcester, J. A. Mercer, and R. C. Spindel
4. Semiclassical Approximations and Predictability in Ocean Acoustics; M. G. Brown

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